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# Will EU biofuel policies affect global agricultural markets?

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**Summary**

This article assesses the implications of the EU Biofuels Directive (BFD) using a computable general equilibrium framework with endogenous land supply. The results show that, without policy intervention to stimulate the use of biofuel crops, the targets of the BFD will not be met. With the BFD, the enhanced demand for biofuel crops has a strong impact on agriculture globally and within Europe, leading to an increase in land use. On the other hand, the long-term declining trend in real agricultural prices may slow down or even reverse.

**Keywords:** biofuels, EU Biofuels Directive, agricultural markets, computable general equilibrium modelling, endogenous land supply

**JEL classification:** F17, Q17, Q27, Q28

## 1. Introduction

World wide production of biofuels is growing rapidly. From 2001 to 2007, world ethanol production almost tripled from 20 to 50 billion litres (Licht, 2007), and world biodiesel production grew from 0.8 to almost 4 billion litres. In Europe, biodiesel production (5.5 million tonnes) is higher and growing faster than ethanol production (2.0 million tonnes). Stimulated by tax exemptions, almost half the EU biodiesel is produced in Germany (Figure 1).

In the European Union (EU) in 2004, only about 0.4 per cent of EU cereal and 0.8 per cent of EU sugar beet production were used for bioethanol, while more than 20 per cent of oilseeds was processed into biodiesel. The annual growth rate of bioethanol and biodiesel between 2005 and 2007 was 53 per cent and 44 per cent, respectively (Licht, 2007).

A first shift towards biofuel production was in response to high oil prices in the 1970s due to supply restrictions by the Organization of the Petroleum Exporting Countries (OPEC) cartel (Figure 2). High oil prices encouraged innovations that saved oil and triggered governments to stimulate production and use of more reliable substitutes, such as biofuels, and world bioethanol production reached approximately 15 billion litres in 1985. In 1986, crude

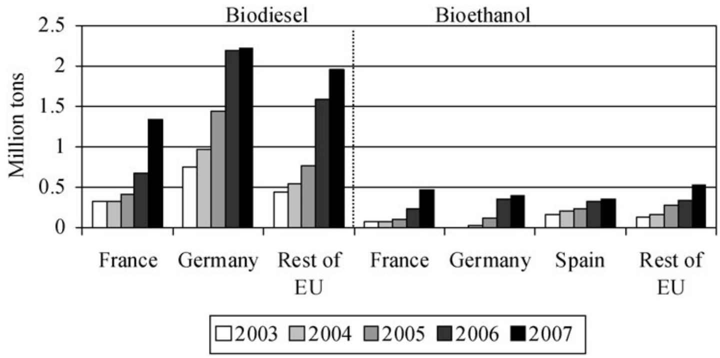


**Figure 1.** Biodiesel and bioethanol production (million tons) in selected EU regions, 2003–2007. *Source*: Data derived from Licht (2007).

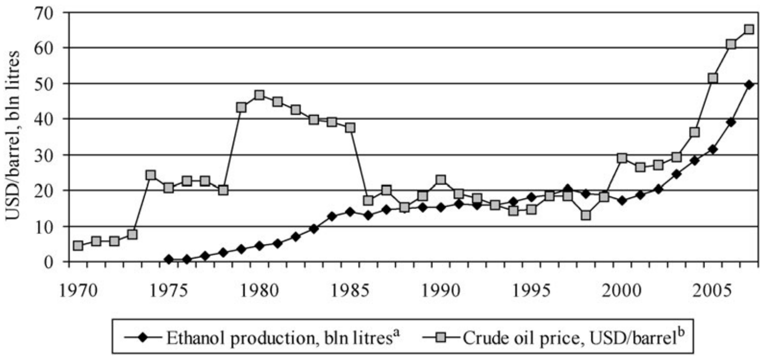


**Figure 2.** World fuel ethanol production and crude oil prices, 1970–2007. (a) Licht (2007). (b) Real prices. Crude petroleum. World Bank Database (Constant 1990 USD). (1 barrel = 159 litres.)

oil prices almost halved and fluctuated around $20 per barrel until the beginning of the new millennium. Biofuel production increased only marginally after 1985. The recent increase in the price of oil and policy incentives motivated by these high prices as well as environmental concerns have led to the recent biofuel boom. The only mature, integrated biofuel market in practice is Brazil's cane-based ethanol market. In this ethanol-electricity cogeneration system, sugar cane is a competitive energy provider (Schmidhuber, 2006).

Biofuel production in the EU, the United States and Canada is driven mainly by policy measures, including tax exemptions, investment subsidies and obligatory blending of biofuels with mineral fuels. In the United States, ethanol as a gasoline oxygenate replacing highly toxic methyl tertiary-butyl ether (MTBE) originally traded at a premium price above its energy value. As the supply of ethanol exceeded the amount needed to replace MTBE, the oxygenate premium dropped sharply and US ethanol markets became more vulnerable (Birur *et al.*, 2007).

Currently, biofuels can only be commercially produced by processing agricultural crops. These 'first-generation biofuels' may be used in low-percentage blends with conventional fuels in most vehicles and may be distributed through the current fuel marketing infrastructure. However, the transportation of pure ethanol to refineries requires investment because pure ethanol cannot be transported by current tankers (Tyner *et al.*, 2008). Advanced conversion technologies are required for a second-generation of biofuels. The second-generation will use a wider range of biomass resources – agriculture, forestry and waste materials – and promises to achieve larger reductions in greenhouse gas emissions. At the moment, second-generation biofuels cannot be produced at a commercial level, and opinions differ about its role in the future of energy production (Hoogwijk *et al.*, 2005; Smeets *et al.*, 2006).

Given current policy developments and the limitations of availability of only first-generation biofuels, increased biofuel production due to 'pure' market forces and/or 'policy' may have significant impacts on agricultural markets, including world prices, production, trade flows and land use. Linkages between food and energy production include the competition for land and other production inputs, while an increasing supply of by-products of biofuel production, such as dried distillers grain, oil cake and gluten feed, affects animal production. Furthermore, a biofuel boom raises concerns about the impacts of potential increases in food prices on low-income groups of the population as well as the possibility of biodiversity loss due to increased use of land. These implications are poorly understood.

This article assesses the global and sectoral implications of the EU *Directive on the Promotion of Use of Biofuels* (European Commission, 2003) and the *Progress Report on Biofuels* of the European Commission (2007a), which includes a biofuel directive setting a mandatory minimum share of biofuels in total fuel consumption in the transport sector of 10 per cent per member state by 2020. The EU Biofuels Directive (BFD) requires EU member states to ensure that biofuels and other renewable fuels attain a minimum share of total transport fuel consumed. This share (measured in terms of energy content) should be 5.75 per cent by the end of 2010 and 10 per cent by the end of 2020. These goals are not yet mandatory, but this will change for the 2020 target if the recent proposal of the European Commission is approved by the European Parliament and member states (European Commission, 2008). However, most EU member states are far from reaching the target of 5.75 per cent in 2010, with an average biofuel use in EU25 of 1 per cent in 2005 (European Commission 2007a, see also Table A1). Therefore, the question remains whether the objective can be reached in 2010 or 2020.

As in the EU, the main drivers for increased biofuel demand in the United States are high energy prices and incentives provided by the Energy Policy Act of 2005 (EPACT05). The EPACT05 requires a minimum of 28.7 billion litres of renewable fuels (ethanol and biodiesel) to be used in the nation's motor fuel by 2012. Most industry and agriculture experts

(Tokgoz *et al.*, 2007) project that ethanol production will top out around 57 billion litres by 2012, which is equivalent to 7 per cent of projected gasoline consumption by energy content (US Energy Information Administration, 2008). Apart from the EU and the US, other countries such as Canada, Brazil, Australia, India and China have also implemented targets for biofuel volumes and market shares. With a focus on the impact of the European BFD on production, land use and trade, this article contributes to current discussion of the growing competition for land resources between food, feed, fibre and fuel production.

The economic literature on the impact of biofuels on agricultural markets is sparse, as the biofuel boom has occurred quite recently. Rajagopal and Zilberman (2007) provide a comprehensive survey and conclude that the current literature is lacking in many respects. Most economic models do not capture the dynamic interactions between agricultural and energy markets that are important in explaining the timing of adoption and diffusion of biofuels. Many models do not explicitly use oil prices, restrict the policy measures analysed to mandates and lack analysis of international trade aspects of biofuels. Rajagopal and Zilberman (2007: 48) state that 'biofuels affect not only farmers, but also affect agro-industries, the well-being of consumers, balance of trade, and the government budget. Understanding the impacts of biofuels on the overall economy requires a modelling framework that accounts for the feedback mechanisms between biofuels and other markets. The technique that would allow for an assessment of such effects is a computable general equilibrium (CGE) analysis' (Sadoulet and de Janvry, 1995).

By using a global, multi-region, multi-sector CGE model, this article seeks to improve understanding of the international trade aspects of biofuels and biofuel policies. In this first attempt, we focus on first-generation biofuels only. In addition to the extensions directly related to modelling biofuels, some key characteristics of related markets have been included. A distinguishing feature of our method is the introduction of a land supply curve to represent the process of land conversion and land abandonment endogenously (van Meijl *et al.*, 2006; Eickhout *et al.*, forthcoming). In their overview article on land use and CGE models, Hertel *et al.* (forthcoming) state: 'The beauty of this approach [the land supply curve presented by van Meijl *et al.*, 2006)] lies in the way they build up this supply curve. In particular they capitalize on detailed productivity information available from the IMAGE database.' Furthermore, agricultural labour and capital markets are segmented from factor markets in the rest of the economy.

Section 2 of this article describes the methodological improvements in the modelling tool applied. The scenarios analysed – 'EU Biofuels Directive' and 'higher oil prices' – are introduced in Section 3. Section 4 presents the simulation results and offers sensitivity analyses with regard to key model parameters such as the elasticity of substitution between biofuels and fossil fuels, and the Armington trade elasticities. The final section summarises and concludes.

## 2. Modelling of biofuels

Following recommendations by Rajagopal and Zilberman (2007), a CGE model is applied here. So far, many analyses have been done with partial equilibrium models where the existing models of the agricultural sector receive an exogenous increase in demand for feedstock used in biofuel production (e.g. maize, sugar cane, wheat, sugar beet, oilseeds, etc.) to determine the changes in long-run equilibrium prices and the implications for welfare (OECD, 2006; European Commission, 2007b; Nowicki *et al.*, 2007). A first category of CGE studies analysed the impact of biofuel and carbon targets on the national economy (McDonald *et al.*, 2006; Dixon *et al.*, 2007; Reilly and Paltsev, 2007), and a second emphasised international trade (Gohin and Moschini, 2007; Birur *et al.*, 2007). Rajagopal and Zilberman (2007) argued for a better understanding of the dynamics and international trade aspects of biofuels. Existing studies either treat land supply exogenously, or only account for it implicitly by incorporating the land supply effects in the price elasticities of area use, despite the fact that economic (competitiveness and trade) and environmental (especially biodiversity) impacts are related to land use. Therefore, our methodological improvements focus on the integration of the energy and land markets, with special attention to land-use change.

This section describes the methodological improvements performed and considered crucial for modelling biofuels in a global general equilibrium model. First, we introduce the standard general equilibrium model (including the data) that is used as a starting point. Second, the extensions of the energy markets necessary to model biofuel demand are discussed and, third, improvements to the modelling of factor markets are discussed with an emphasis on land markets. Since 2001, the Global Trade Analysis Project (GTAP) database does not fully account for biofuel use and its rapid development in the last five years, the original data have been adjusted. This section concludes with a description of the adjustments to the model's data base.

### 2.1. Standard GTAP model features

Our model builds on a modified version of the GTAP multi-sector, multi-region CGE model (Hertel, 1997). Its multi-region specification allows the inter-country effects expected from the BFD (that affects demand and supply in the EU) to be captured, and consequently also prices and trade flows on global markets. The multi-sector dimension makes it possible to study the link between energy, transport and agricultural markets.

In the standard GTAP model, all sectors produce under constant returns to scale. Perfect competition on factor and output markets is assumed. Firms transform intermediate inputs and primary production factors (i.e. natural resources, labour and capital) into products. Intermediate inputs are used in fixed proportions but are constant elasticity of substitution (CES) composites of domestic and region-specific foreign components (Armington assumption). This permits the modelling of bilateral (intra-industry) trade flows, dependent

on the ease of substitution between products from different regions. Primary factors are combined according to a CES function. Regional endowments of natural resources, labour and capital are fixed. Labour and capital are perfectly mobile across domestic sectors. Agricultural land, on the other hand, is imperfectly mobile across alternative agricultural uses, hence sustaining rent differentials. Each region is equipped with one regional household that distributes income across savings and consumption expenditures according to fixed budget shares. Consumption expenditures are allocated across commodities according to a non-homothetic constant difference elasticity (CDE) of substitution expenditure function.

### 2.2. GTAP data used

Version 6 of the GTAP data is used. The database contains detailed bilateral trade, transport and protection data for the base year, 2001, characterising economic linkages among regions that are connected to individual country input–output databases accounting for intersectoral linkages. All monetary values of the data are in millions of US dollars. In our simulations, the 88 GTAP regions are aggregated to 37 regions, including all EU15 countries (with Belgium and Luxembourg as one region) and the remaining EU countries (Baltic countries as one region, Malta and Cyprus as one region, and Bulgaria and Romania as one region), as well as the most important countries and regions outside the EU from an agricultural production and demand point of view (i.e. Brazil, NAFTA, East Asia and the Rest of Asia, and three regions within Africa). The 57 GTAP sectors are aggregated to 23 sectors, differentiating in detail the land-using agricultural sectors (with grains, wheat, oilseeds, sugar cane and sugar beet being especially relevant for biofuel production), and the sectors that are important from an energy perspective (e.g. crude oil, petroleum, gas, coal and electricity).

### 2.3. Energy markets

The model is extended by introducing energy–capital substitution as described in the GTAP-E model (Burniaux and Truong, 2002). The GTAP-E model aggregates all energy-related inputs for the energy sectors – such as crude oil, gas, electricity, coal and petrol products – in the value added nest (left part of Figure 3). At the highest level, the energy-related inputs and the capital inputs are modelled as an aggregated ‘capital-energy’ composite.

To introduce the demand for biofuels, the nested CES function of the GTAP-E model is adjusted and extended to model the substitution between different categories of oil (oil from biofuel crops and crude oil), ethanol and petroleum products in the value-added nest of the petroleum sector. For this purpose, the non-coal aggregate is modelled the following way: (i) it consists of two sub-aggregates, fuel and gas; (ii) fuel combines vegetable oil, oil,

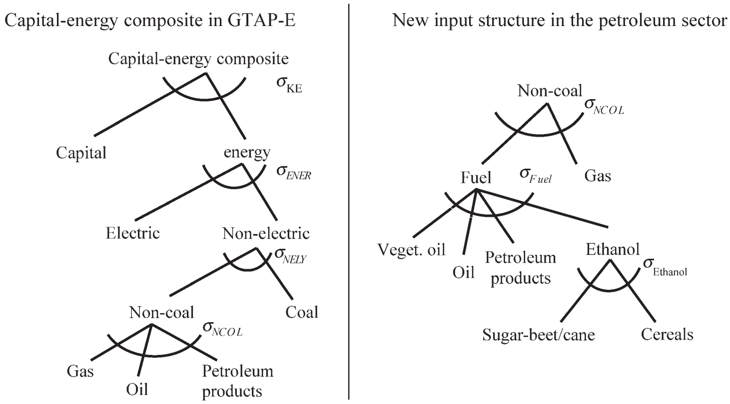


**Figure 3.** Nesting structure in energy modelling.

petroleum products and ethanol; and (iii) ethanol is made out of sugar beet/ sugar cane and cereals (right-hand part of Figure 3).[1]

The nested CES structure implies that biofuel demand is determined by the relative prices of crude oil versus agricultural products, including taxes and subsidies. With this approach, we model the mix of agricultural and fossil inputs with a CES. In reality, however, biofuel demand may not depend on the price of fossil inputs when these prices are very low and biofuels are not competitive. In the area where ethanol prices are just competitive with fossil gasoline prices, demand response to price changes might be very elastic, provided the actual blending ratio is not close to its technical limits (when demand becomes very inelastic). As Schmidhuber (2007) argued, if oil prices stay high, food and energy markets will be more interlinked. Oil prices will then put both a floor and a ceiling to prices in food markets. The ceiling price effect implies that, as feedstock costs are the most important cost element of all (large-scale) forms of bioenergy use, feedstock prices (food and agricultural prices) cannot rise faster than energy prices in order for agriculture to remain competitive in energy markets. The floor price effect implies that if demand is particularly pronounced, as in the case of cane-based ethanol, bioenergy demand has created a quasi-intervention system and an effective floor price for sugar in this case.

Also important is the initial share of biofuels in fuel production. Finally, the substitution possibilities between crude oil and biofuels (represented by the substitution elasticities $\sigma_{Fuel}$ and $\sigma_{Ethanol}$) are crucial. The values of the elasticity of substitution are taken from Birur *et al.* (2007) who, based on a historical simulation of the period 2001 to 2006, obtained values of 3.0 for the US, 2.75 for the EU and 1.0 for Brazil. These values are applied here for the years 2001 to 2010, and are increased by 50 per cent the years 2010 to 2020, since

1 Ethanol is not modelled as a product for final demand but only as an aggregate composite input in the petrol industry.

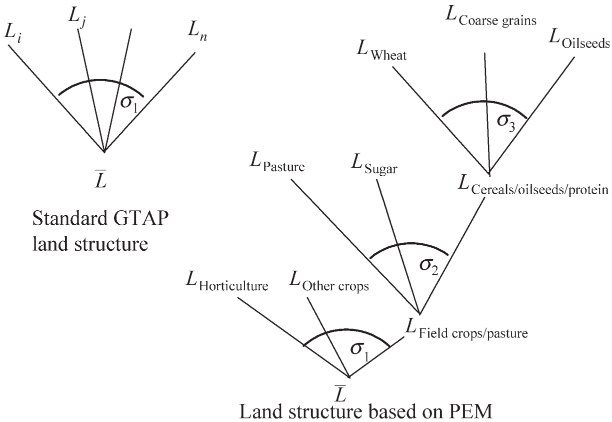


**Figure 4.** Land allocation tree in the extended version of GTAP.

we expect that biofuels and fossil fuels will become closer substitutes over time due to technological progress.

The focus of this article is on the mandatory blending requirement in the BFD. This directive fixes the share of biofuels in transport fuel. It should be mentioned that this mandatory blending is budget-neutral from a government point of view. To achieve this in a CGE model involves implementing two policies. First, the biofuel share of transport fuel is specified and made exogenous such that it can be set at a certain target. An endogenous subsidy is modelled to achieve the required biofuel share.[2] Second, to ensure that this incentive instrument is budget-neutral, the biofuels subsidy is counter-financed by an end-user tax on petrol consumption, implying that the petrol user pays for the extra cost involved for using fuel with higher biofuel blending rates.

## 2.4. Allocation of agricultural land

To analyse the impact of biofuels, the functioning of the land market is particularly crucial. Birur *et al.* (2007) used agro-ecological zones in combination with an exogenous land supply, following the methodology outlined in Lee *et al.* (2005). We propose an alternative to traditional methods by introducing a new demand structure that reflects the different degrees of substitutability between agricultural land uses according to the crops considered (Huang *et al.*, 2004). The standard version of GTAP represents land allocation in a constant elasticity of transformation (CET) structure (left side of Figure 4), assuming that the various types of land use are imperfect substitutes. This simple land use allocation structure is extended by creating a nested

2 In a general equilibrium model, the number of endogenous variables must be equal to the number of equations. Therefore, if we make one variable (biofuel share) exogenous, one other variable (input subsidy) must be made endogenous. This is called a closure swap.

three-level CET-structure that takes into account differential degrees of substitutability between types of land use (right-hand side of Figure 4; see Huang *et al.*, 2004), using the elasticities from the OECD Policy Evaluation Model (OECD, 2003). In this structure it is assumed that the substitution is easier between wheat and oilseeds, for example, than between horticulture and field crops, i.e. that $\sigma_3 > \sigma_2 > \sigma_1$.

## 2.5. The land supply curve

Total land supply is exogenous in the standard GTAP model. In this extended version, total agricultural land supply is modelled using a land supply curve specifying the relationship between land supply and a land rental rate in each region (van Meijl *et al.*, 2006). Land supply to agriculture can be adjusted by idling agricultural land, converting non-agricultural land to agriculture, converting agricultural land to urban use and agricultural land abandonment.

Figure 5 gives the general idea behind the land supply curve. When agricultural land use approaches maximum potential land use ($\bar{L}$), farmers are forced to use less productive land with higher production costs (strongly increasing part of the supply curve). As a consequence, in land-abundant regions like South America and for members of NAFTA, an increase in demand from $D_1$ to $D_1^*$ (left-hand side of Figure 5) results in a large increase in land use (from $l_1$ to $l_2$) and a modest increase in rental rates (from $r_1$ to $r_2$), while land scarce regions like Japan, Korea and Europe experience a small increase in land use and a large increase in the rental rate (right-hand side of Figure 5; shift from $D_2$ to $D_2^*$). These land price differences will influence the competitiveness of biofuel production.

The key problem is the empirical implementation of this land supply curve for all major regions in the world, as land price data are not available on

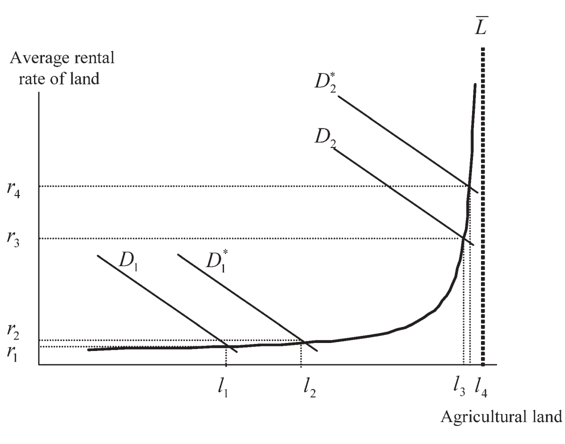


**Figure 5.** Impact of increased land demand for biofuel crops on land markets.

a global scale. Eickhout *et al.* (2007) used biophysical data, such as spatially varying land productivity, from the IMAGE model to approximate the supply curve. For the EU15 countries, more information on land prices is available, and empirical estimates have been used here (Cixous, 2006).

Perfect capital and labour mobility between agricultural and non-agricultural sectors, as assumed in the standard GTAP, implies equal remuneration for these production factors. This is not supported by empirical evidence (De Janvry *et al.*, 1991). Therefore, capital and labour market segmentation is introduced by specifying a CET structure (Keeney and Hertel, 2005). The elasticities of transformation have been calibrated to fit estimates of the elasticity of labour supply from PEM (OECD, 2003).

### 2.6. Agricultural policies

Agricultural policies are crucial for the development of biofuels. As this article focuses on the BFD, some key features of the EU Common Agricultural Policy have been included, such as agricultural quotas (milk and sugar) implemented as a complementarity problem (van Meijl and van Tongeren, 2002).

### 2.7. Adjustment of the GTAP 6 database towards biofuels

Developments in the biofuel sector are extremely rapid. Therefore, the GTAP database has been updated to include recent developments. The data on the use of biofuel crops (grain, sugar and oilseeds) in the petrol sector are derived from Licht (2007), Eurostat and European Commission (2007a). In the adjustment process, the total intermediate use of these agricultural products at the national level has been kept constant while the input use in non-petroleum sectors has been adjusted in an endogenous procedure to reproduce 2004 biofuels shares in the petroleum sector (corrected for their energy contents) (see Table A1).

Also other data like quota rents on sugar and milk, sugar beet use in the production of sugar, oilseed use in the production of vegetable oils and fats have been adjusted (Kleinhans *et al.*, 2001; Jensen and Nielsen, 2004; van Meijl *et al.*, 2006). FAO-based information on land use in the agricultural sectors is added to the database.

## 3. Description of scenarios

The ‘Global Economy’ scenario of the EUruralis project is used as a reference scenario to assess the impact of biofuels and related polices (Wageningen UR and Netherlands Environmental Assessment Agency, 2007). The ‘Global Economy’ scenario is an elaboration of one of the four emission scenarios of the Intergovernmental Panel on Climate Change (IPCC), as published in its *Special Report on Emission Scenarios* (SRES) (Nakicenovic and Swart, 2000). In the analysis published by the Netherlands Bureau for Economic

Policy Analysis (CPB), there is a detailed focus on Europe with more regional and sectoral disaggregation (CPB, 2003).

Under the 'Global Economy' scenario, which elaborates the A1 scenario of the SRES, the World Trade Organisation (WTO) negotiations are assumed to have concluded and global trade to be moving towards full liberalisation (Table 1).

**Table 1.** Assumptions of reference or 'Global Economy' scenario

| | |
|---|---|
| Trade policies | Stepwise elimination of all trade barriers<br>• 2010: 25% reduction compared with 2001<br>• 2020: 50% reduction compared with 2010 |
| Domestic support in agriculture | CAP reform 2003: full decoupling<br>• 2010: 25% reduction of domestic support, new EU member states' domestic agricultural support agreed by EU minus 25% reduction<br>• 2020: 50% reduction compared to 2010 |
| Production quotas | 2020: abolished |
| Biofuels | No blending obligations |
| Set aside | Abolished in EU15 in 2010, never introduced in New Member States |

Important driving forces are demographic, macro-economic and technological developments as well as policy assumptions. Demographic and macro-economic assumptions are taken from studies that implement the SRES. The population numbers are taken directly from SRES scenarios (Nakicenovic and Swart, 2000). Yearly GDP growth (between 1.7 per cent per year in Japan and Korea and 6.4 per cent in East Asia) and consistent employment and capital growth per scenario are taken from CPB (2003), which used the CPB macro-economic Worldscan model. The scenarios are constructed through recursive updating of the database for two consecutive time periods (i.e. 2001–2010, 2010–2020) such that exogenous GDP targets are met, given the exogenous estimates on factor endowments (skilled labour, unskilled labour, capital and natural resources) and population. The procedure implies that technological change is endogenously determined within the model. In line with CPB, we assume common trends for relative sectoral total factor productivity growth. We deviate slightly from the CPB assumptions that all inputs achieve the same level of technical progress within a sector (i.e. Hicks neutral technical change) by allowing land productivity to be determined by additional information on yields from FAO and the IMAGE model.

In the policy scenario, the implementation of the BFD is applied as an example of a mandatory blending obligation and illustrates the consequences of this biofuel policy on the national and international markets for agri-food products. In this scenario, a 5.75 per cent mandatory blending rate is applied

in 2010, and a 10 per cent mandatory blending rate is applied in 2020 in each EU member state.

Since the biofuel market is surrounded with uncertainties, two additional scenarios have been calculated with regard to the development of world crude oil prices. Under the scenarios 'Reference, high oil price' and 'BFD, high oil price', the oil price increase is 70 per cent higher than in the reference or the BFD scenarios. A sensitivity analysis has been conducted with regard to some crucial model parameters such as the elasticity of substitution between different inputs in the petroleum industry and the Armington elasticities on trade.

## 4. Results of the simulation analysis

The results for the reference scenario, as well as the biofuel policy and oil price scenarios, are presented in this section. Note that the only change under the two policy scenarios is the mandatory blending obligation within the EU. All other policy instruments remain those of the reference scenario. This section concludes with a sensitivity analysis with regard to some important model parameters.

### 4.1. Scenario results

With enhanced biofuel consumption due to the BFD (5.75 per cent in 2010 and 10 per cent in 2020), real prices of agricultural products, especially biofuel crops, tend to decrease less than in the reference scenario (Figure 6). Under the reference scenario, real world prices for agricultural products tend to decline and conform to their long-term trend. This is because of inelastic food demand together with a high rate of productivity growth (Schmidhuber,

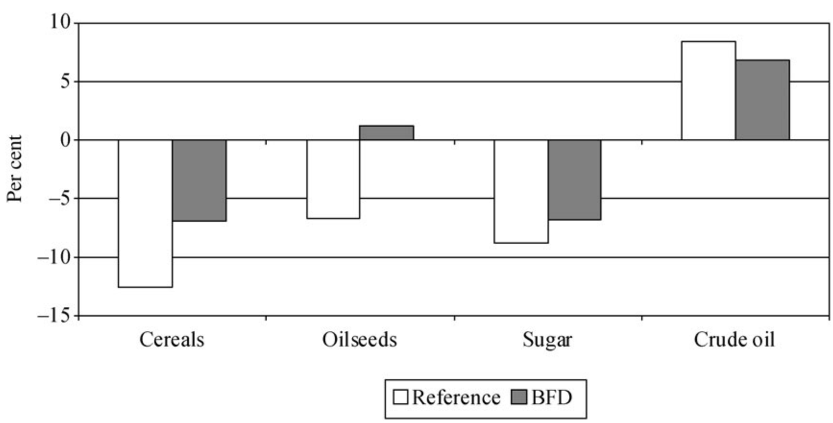


**Figure 6.** Percentage change in real world prices, 2020 relative to 2001.

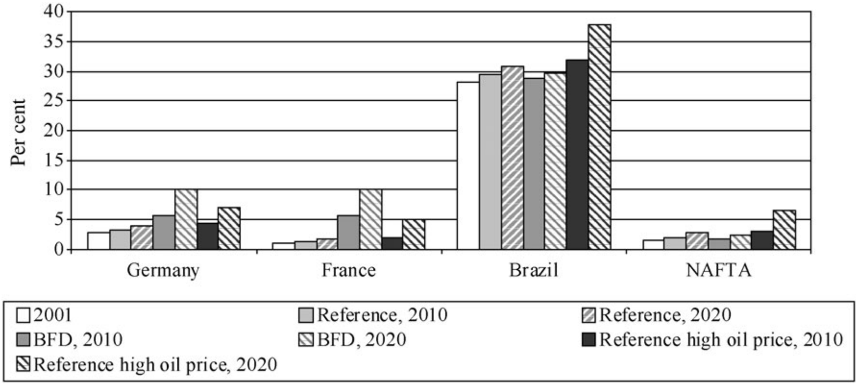


**Figure 7.** Percentage share of biofuels in transport fuel consumption for selected regions, 2001, 2010 and 2020.

2007).[3] The oilseed sector has the highest price difference, because biofuels in EU transport are dominated by biodiesel from oilseeds.[4]

The increase in world prices is less than in some other global studies (e.g. Msangi *et al.*, 2007) where oilseed and sugar prices are projected to rise 18 and 10 per cent, respectively. These studies also include non-EU policies in their analysis, and exclude the effect that a higher biofuel demand generates extra land supply through land price increases and therefore mitigates parts of these land price increases (Figures 10 and 11, respectively). The crude oil price declines slightly (1.5 per cent) as demand for crude oil diminishes due to the introduction of the BFD. Similarly, Dixon *et al.* (2007) showed a decline in the world crude oil price of 4.5 per cent due to US biofuel policies.

Even without mandatory blending, the share of biofuels in fuel consumption for transportation purposes increases slightly (Figure 7). This is because the ratio between the crude oil price and prices for biofuel crops changes in favour of biofuel crops (Figure 6).[5] Nevertheless, the results reveal that, without mandatory blending, the 5.75 and 10 per cent biofuel targets will not be reached in EU member states, even under a scenario with a strong increase in crude oil price (Figure 7).

Fulfilling the required blending rates occurs at the expense of biofuel consumption in non-European countries. The decrease in the crude oil price and the rise in biofuel prices lead to declines in the biofuel consumption share of

3 The reference scenario of this article is based on the projection of long-term trends on global agriculture and food markets, and therefore does not include the current steep price rises in agri-food markets.

4 This analysis might overstate the price effect for oilseeds because it does not explicitly consider the negative impact on the protein feed part of oil meal. This is particularly the case if feed by-products from grain-based ethanol production are taken into account, which would push down oil meal prices further.

5 Our assumption of a CES approach might overestimate the real development of biofuel consumption in the absence of mandatory blending targets, as biofuels are not (yet) competitive. However, the endogenous growth under the reference scenario is low.

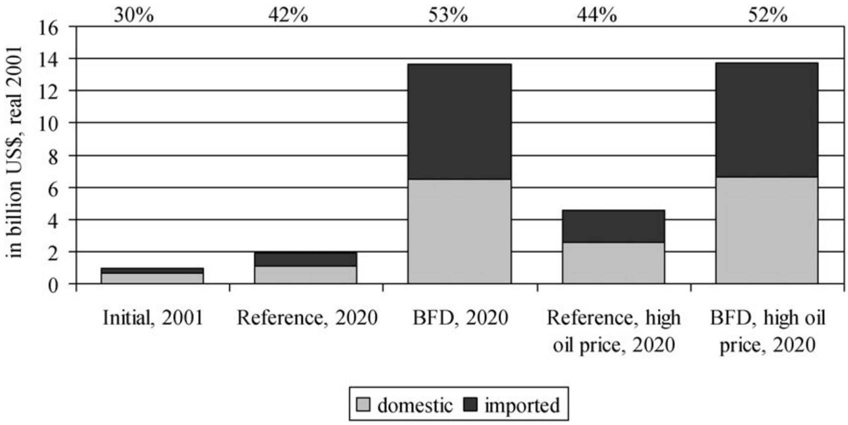


**Figure 8.** Origin of biofuel crops used in EU-27 (in billion US$, real 2001), situation in 2001 and results of four scenarios. *Note:* Percentages indicate the share of imported biofuel crops in total use of biofuel crops in petrol sector.

1 per cent in Brazil and 5 per cent in NAFTA. The decline is smaller in Brazil because its elasticity of substitution between crude oil and biofuels is lower than in NAFTA. Overall, the Biofuels Directive in Europe generates a decrease in worldwide crude oil use.

In the BFD scenario, the demand for biofuel crops used by the EU petrol sector is US $14 billion (in 2001 dollars) under the minimum blending requirement of 10 per cent in 2020 (Figure 8). The import share increases from 42 per cent in the reference scenario to 53 per cent in the BFD case. The increased demand for biofuel products in the EU leads to higher land and product prices in the EU relative to land-abundant countries, which are often exporters to the EU market.

The estimated import shares of biofuels are much higher than the 20 per cent assumed by the EU Commission (2007b), which are based on the assumption that second-generation biofuel crops will cover 30 per cent of required inputs in 2020. It is questionable, however, whether this assumption is realistic (Wiesenthal *et al.*, 2007). According to von Lampe (2007: 235), a 'European biofuel industry [based] on biodiesel is likely to require substantial additional imports of vegetable oils'. Banse and Grethe (2008) estimated the import share of biofuels at 35 per cent without second-generation biofuels. These three publications are based on models that do not take endogenous land supply into account.

Consistent with the argument above, Figure 9 shows that the BFD will increase the EU trade deficit for biofuel crops, and increase the trade surplus in land-abundant countries like South and Central America and NAFTA. If, however, the oil price rises, the EU and NAFTA will need more biofuels and consequently will increase their imports and respectively reduce net exports. Southern and Central America, and to a lesser extent Africa, have both abundant land and a smaller substitution elasticity

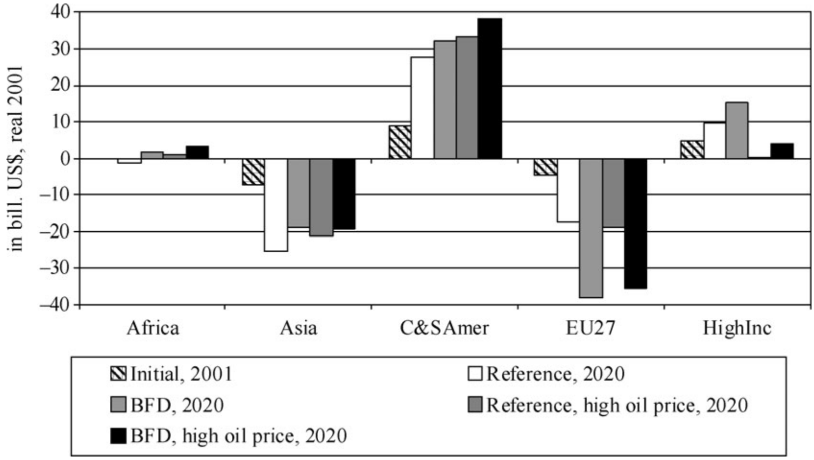


**Figure 9.** Net exports of biofuel crops (US$ billion, real 2001) by region, initial situation and by scenario.

between crude oil and biofuels, leading to increasing net exports with an increasing crude oil price.

As a consequence of the processes described above, a European Biofuels Directive increases the production of biofuel crops mainly in the EU, and in Central and South America. Table 2 shows the changes in oilseed production, which expands significantly under the policy scenarios as EU biofuel is based on biodiesel. Oilseed production in the EU27 increases from almost 6 per cent in the reference to 41 per cent in the BFD scenario. In the case of the US biofuel initiative, cereal production (especially maize) increases strongly (Birur *et al.*, 2007).

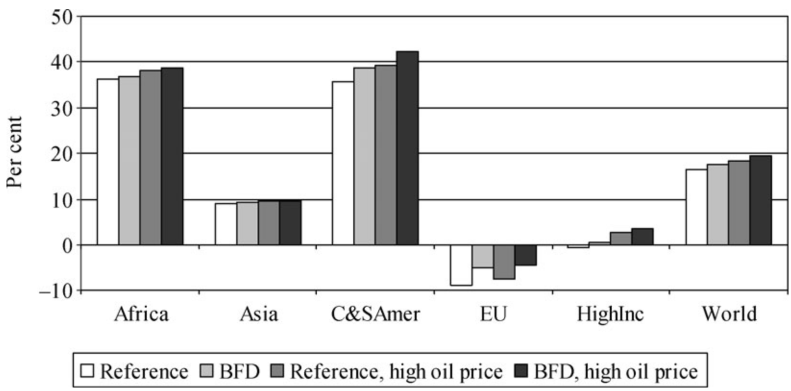


**Figure 10.** Percentage change in total agricultural land use by region and scenario, 2020 relative to 2001.

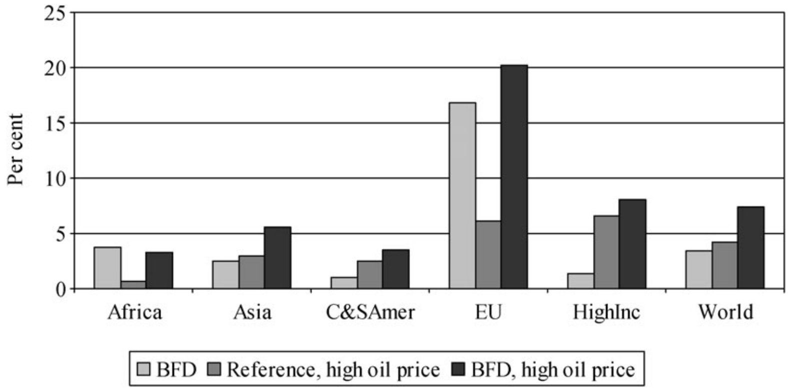


**Figure 11.** Percentage change in price of agricultural land by region and scenario, 2020 relative to the reference scenario 2020.

**Table 2.** Percentage change in agricultural production by region and scenario, 2020 relative to 2001

| | Africa | Asia | C&SAmer | EU | HighInc | NAFTA | World |
|---|---|---|---|---|---|---|---|
| Arable crops | | | | | | | |
| Reference | 68.2 | 46.9 | 51.4 | 14.2 | 18.5 | 39.3 | 36.2 |
| BFD | 68.8 | 47.0 | 56.5 | 17.7 | 19.7 | 41.2 | 37.5 |
| Ref., high oil price | 70.2 | 48.6 | 57.7 | 15.1 | 24.0 | 48.5 | 38.9 |
| BFD, high oil price | 70.8 | 48.6 | 61.6 | 17.4 | 24.9 | 49.9 | 39.9 |
| Biofuel crops | | | | | | | |
| Reference | 103.3 | 68.0 | 73.1 | −12.2 | 22.5 | 26.8 | 41.0 |
| BFD | 111.3 | 70.0 | 86.1 | 6.4 | 25.4 | 29.8 | 48.6 |
| Ref., high oil price | 112.2 | 79.8 | 95.9 | −4.1 | 36.3 | 41.8 | 53.4 |
| BFD, high oil price | 118.6 | 81.2 | 106.1 | 9.0 | 38.4 | 43.8 | 59.1 |
| Oilseeds | | | | | | | |
| Reference | 91.0 | 61.4 | 66.0 | 5.6 | 56.8 | 58.6 | 55.1 |
| BFD | 102.7 | 63.7 | 84.7 | 41.3 | 65.4 | 67.6 | 66.1 |
| Ref., high oil price | 117.8 | 77.7 | 90.6 | 22.9 | 93.8 | 97.1 | 78.4 |
| BFD, high oil price | 126.5 | 79.1 | 104.5 | 44.1 | 99.1 | 102.6 | 85.7 |

Apart from the direct impact of an increase in biofuel demand on prices and production, the changes in agricultural income are significant. EU farm income[6] increases relative to the reference scenario (where farm income declined after reduction of income and price support), mainly due to higher agricultural prices.

6 Farm income is defined as the sum of remuneration of production factors (land, labour, capital), farm subsidies and quota rents (sugar, milk) in all primary agricultural sectors.

A higher oil price leads to an increase in production of biofuel crops in all regions of the world, especially in South America, where both domestic demand (Figure 7) and net exports (Figure 9) increase, and in NAFTA, where domestic demand is the driving force (Figure 7). As a consequence, the share of agricultural land used for biofuel crops increases to 3.1 per cent in South and Central America and 7.3 per cent in the EU. This pressure increases land use in South and Central America and reduces land abandonment in the EU (Figure 10). For oil price increases, the pressure on land use is more equally distributed across the world with stronger pressure on land use in the HighInc region (including NAFTA, Japan, Korea, Australia and New Zealand) because of the combination of relative land abundance and a high substitution elasticity between biofuels and crude oil.

Compared with the reference scenario, land use increases under the BFD and high oil price scenarios in all regions. The expansion of agricultural land use on a global scale – and especially in land-abundant South America – suggests that extra biofuels will be at the cost of biodiversity (CBD, 2006).

The Biofuels Directive affects land prices at the global level. Compared with the reference scenario, land prices are higher: between 1 per cent in Central and South America and 16 per cent in the EU. High prices for crude oil boost the use of biofuel crops in fuel production and also affect land prices. If high oil prices coincide with the BFD blending target, land prices increase by more than 7 per cent globally and by more than 20 per cent in the EU (Figure 11).

Increasing biofuel crop production stimulates demand for agricultural land used for biofuel cropping. Under the reference scenario, the share of land sown with biofuel crops increases from 0.3 per cent to 1.2 per cent globally. In 2001, the model's base year, the share of biofuel crop land is the highest in Central and South America (0.7 per cent) followed by the European Union (0.6 per cent). Under the reference scenario, the share of land used for biofuel crops increases to 1.8 per cent in the EU and to 1.5 per cent in Central and South America. Under the BFD scenario, in contrast, more than 7 per cent of agricultural land in the EU is sown with biofuel crops. The area used for biofuel crops also expands in Central and South America as well as in high-income countries. A similar effect is observed for the reference scenario with a high oil price. In fact, the impact of a high oil price is greater compared with the BFD in high-income countries, as domestic use and production increase more under this scenario. Therefore, at the global level, land used for biofuel cropping is more affected by high oil prices than by the European BFD. However, at the regional level, important land use changes occur due to the European biofuel policies in the EU itself, and also in Central and South America as main exporting regions for Europe.

As outlined above, the mandatory blending requirement for the petrol sector implies an increase in petrol price because biofuels are more expensive than crude oil. To meet the 5.75 per cent obligations in 2010, the petrol price will rise by 2 per cent, and a 6 per cent petrol price increase accompanies

the 10 per cent BFD target in 2020.[7] The implicit budget-neutral subsidies on biofuel crops in the petroleum sector, which are required to meet the targets by making feedstock competitive with crude oil, are high and range from 30 per cent in Sweden to almost 60 per cent in the UK in 2020.[8] In general, the required additional implicit subsidies are inversely related to the initial biofuel shares in transportation fuel (see Table A1). These additional subsidies indicate the difficulties that most EU member states will have in trying to meet the targets of the BFD. These difficulties may be offset if technical change in biofuel production makes biofuels more competitive, which would require higher yields and especially more efficient conversion technologies (Dale, 2003).

With high oil prices, the subsidies required to implement the biofuel target will drop significantly. In Sweden (the current front-runner in terms of biofuel use in the EU), the subsidy is almost zero.

## 4.2. Sensitivity analyses

For biofuel market development, the elasticity of substitution between fossil fuels and feedstock in the petroleum industry is crucial, yet uncertain. Moreover, the development of international trade and, therefore, regional production and land use heavily depends on the value of the trade (Armington) elasticities. We therefore conducted sensitivity analyses with regard to these two parameters.

The substitution elasticity between fossil fuels and biofuels describes the percentage change of their use ratio, given a 1 per cent change in relative prices. The values applied in this analysis are based on Birur *et al.* (2007). Table A2 shows the results with elasticities 50 per cent above and below the standard values. With higher elasticities, the relative price increase of fossil fuels to biofuels in the reference scenario induces greater replacement of fossil fuels by biofuels, implying higher biofuel shares, world crop prices and land use in EU member states, Brazil and the NAFTA region. With higher substitution elasticities, the net exports of biofuel crops from South and Central America increase by more than 5 per cent. The opposite is true in the case of low substitution elasticities. The size of the elasticities generally has a relatively large impact on variables directly involved in biofuel use and production such as biofuel input use, oilseed production and oilseed world prices.

Table A2 shows that the results are also sensitive to the value of the Armington trade elasticities. If trade elasticities are higher, changes in

7 The rise in petrol prices is the 'hidden' cost to consumers of the EU biofuel directive. The blending requirement improves political feasibility relative to subsidies, which are directly visible in the government budget. Furthermore, petrol prices are very volatile, making it difficult for consumers to separate the impact of the blending obligation from normal price fluctuations. Currently, high food prices in combination with low environmental benefits pose a bigger threat to the political feasibility of the EU biofuel directive compared with higher petrol prices.

8 As described in section 2, the subsidy on biofuel crop use in petrol is modelled as a budget-neutral instrument to the government and counter-financed by end users of petrol. It is an additional subsidy to the existing (biofuel) policies.

international prices have a stronger impact on trade and domestic markets. With larger trade elasticities than in the base scenario, the expansion of EU oilseed production is smaller and biofuel crops become more profitable due to a greater decline in crop prices. As a consequence, the land used for biofuel crops in the EU expands, even though total agricultural area experiences a greater decline compared with the reference scenario.

The sensitivity analyses shows that the qualitative results are not fundamentally different, but the size of the effects can change substantially.

## 5. Summary and conclusions

This analysis shows that enhanced demand for biofuel crops under the BFD has a strong impact on agriculture at both the global and the European levels. The long-term trend of declining real world prices for agricultural products slows down or reverses for the feedstock used for biofuels. The incentive to increase production in the EU will tend to increase land prices and farm incomes in the EU and other regions. Domestically produced biofuel feedstock will only partially meet EU demand and the EU will incur a higher agricultural trade deficit. Biofuel crop production and land use will expand in land-abundant countries (NAFTA and especially in South and Central America) due to increased exports to the EU. The resulting higher feedstock prices will reduce biofuel consumption outside the EU. However, at a global level, biofuel use increases and crude oil demand decreases, leading to a decline in the world price of oil. The expansion of agricultural land use on a global scale, and especially in land-abundant South America, may indicate a decline in biodiversity.

The results depend on the trend in the crude oil price. A higher crude oil price will increase biofuel use, especially in Brazil, NAFTA and the EU. Contrary to the BFD scenario, a higher oil price causes a feedstock trade deficit in NAFTA.

Without the directive or any other additional policies to stimulate the use of biofuel crops in the petroleum sector, the BFD's targets will not be reached in 2010 or 2020. A mandatory blending policy leads to higher consumer prices for petrol, as biofuels are more expensive given current technology and expected long-term crude oil price. The increased demand for feedstock raises their price relative to the oil price and therefore adds to the challenge of making biofuels competitive.

Sensitivity analyses show that the magnitude of the impacts depends on the substitutability between biofuels and crude oil and on the trade elasticities, although the qualitative conclusions do not change.

All our results depend on the relative land availability of countries worldwide. Including a land supply curve is crucial if the impacts of increased demand for biofuels on prices, trade, production, land use and, ultimately, biodiversity are to be studied. The methodology with regard to modelling energy markets could be improved by implementing a more flexible functional form that allows for an elasticity of substitution between fossil fuels and agricultural inputs that is not constant.

Therefore, for biofuels to be competitive in the long run, investments in research and development are needed to obtain higher yields or better conversion technologies. This analysis, however, focuses only on the first-generation biofuels. Decisions on research and development investments should account for second-generation biofuels, as these promise to be both better and more cost-effective in reducing greenhouse gas emissions, although second-generation biofuels will yield fewer by-products than the first-generation biofuels.

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## Appendix

**Table A1.** Biofuel use and targets in EU member states, 2004 and 2005 (per cent of total fuel consumption)

| | 2004 Biofuel share | 2005 Indicative Target | | 2004 Biofuel share | 2005 Indicative Target |
|---|---|---|---|---|---|
| Austria | 0.06 | 2.50 | Latvia | 0.07 | 2.00 |
| Belgium | 0.00 | 2.00 | Lithuania | 0.02 | 2.00 |
| Cyprus | 0.00 | 1.00 | Luxembourg | 0.02 | 0.00 |
| Czech Republic | 1.00 | 3.70[a] | Malta | 0.10 | 0.30 |
| Denmark | 0.00 | 0.10 | Netherlands | 0.01 | 2.00[b] |
| Estonia | 0.00 | 2.00 | Poland | 0.30 | 0.50 |
| Finland | 0.11 | 0.10 | Portugal | 0.00 | 2.00 |
| France | 0.67 | 2.00 | Slovakia | 0.15 | 2.00 |
| Germany | 1.72 | 2.00 | Slovenia | 0.06 | 0.65 |
| Greece | 0.00 | 0.70 | Spain | 0.38 | 2.00 |
| Hungary | 0.00 | 0.60 | Sweden | 2.28 | 3.00 |
| Ireland | 0.00 | 0.06 | UK | 0.04 | 0.19 |
| Italy | 0.50 | 1.00 | EU25 | 0.70 | 1.40 |

[a]2006.
[b]Estimate.
*Source*: European Commission (2007a); Biofuels Progress Report.

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**Table A2.** Sensitivity analyses with regard to the elasticities in trade of and substitution between fossil and biofuels

| | Standard | | Changed trade elasticities | | | | Changed substitution elasticities | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Reference | BFD | Reference | | BFD | | Reference | | BFD | |
| | | | High | Low | High | Low | High | Low | High | Low |
| Percentage change in world price, 2020 relative to 2001 | | | | | | | | | | |
| Cereals | −12.6 | −7.1 | −13.4 | −11.5 | −9.1 | −4.7 | −11.4 | −14.2 | −6.8 | −8.5 |
| Oilseed | −6.8 | 1.2 | −7.6 | −5.6 | −1.3 | 4.1 | −5.0 | −9.4 | 0.8 | 0.7 |
| Percentage share of biofuel crops in fuel consumption for transportation, 2020 relative to 2001 | | | | | | | | | | |
| Germany | 3.8 | 10.0 | 4.4 | 3.5 | 10.0 | 10.0 | 4.0 | 3.4 | 10.0 | 10.0 |
| France | 1.8 | 10.0 | 2.0 | 1.6 | 10.0 | 10.0 | 2.2 | 1.4 | 10.0 | 10.0 |
| Brazil | 30.8 | 29.6 | 30.3 | 31.6 | 29.3 | 30.3 | 32.0 | 29.2 | 30.6 | 28.5 |
| NAFTA | 2.9 | 2.5 | 3.0 | 2.9 | 2.5 | 2.5 | 3.3 | 2.2 | 2.8 | 2.0 |
| Percentage change in oilseed production, 2020 relative to 2001 | | | | | | | | | | |
| Africa | 91.0 | 102.7 | 94.0 | 87.6 | 104.8 | 97.3 | 94.4 | 86.1 | 102.4 | 102.0 |
| Asia | 61.4 | 63.7 | 58.1 | 65.9 | 61.2 | 67.8 | 62.2 | 59.6 | 64.0 | 63.8 |
| C&S America | 66.0 | 84.7 | 70.2 | 58.5 | 85.5 | 78.8 | 71.2 | 59.8 | 84.5 | 84.5 |
| EU | 5.6 | 41.3 | 3.0 | 8.7 | 33.7 | 53.9 | 7.0 | 2.6 | 37.4 | 46.0 |
| High income countries | 56.8 | 65.4 | 58.7 | 53.8 | 67.4 | 60.9 | 63.1 | 46.3 | 68.1 | 61.6 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Percentage change in agricultural land use, 2020 relative to 2001 | | | | | | | | | | |
| Africa | 36.2 | 36.6 | 36.4 | 36.0 | 36.9 | 36.4 | 36.3 | 36.2 | 36.8 | 36.7 |
| Asia | 9.1 | 9.3 | 9.1 | 9.2 | 9.2 | 9.2 | 9.1 | 9.1 | 9.2 | 9.2 |
| C&S America | 35.5 | 38.5 | 35.9 | 34.8 | 38.9 | 37.8 | 36.1 | 34.9 | 39.0 | 38.4 |
| EU | −8.8 | −4.9 | −9.1 | −8.5 | −6.5 | −2.6 | −8.6 | −9.1 | −5.3 | −4.9 |
| High income countries | −0.5 | 0.5 | −0.7 | −0.2 | 0.1 | 0.5 | 0.0 | −1.1 | 0.5 | −0.1 |
| Change in agricultural land use for biofuel crop production (million hectares), 2020 relative to 2001 | | | | | | | | | | |
| Africa | 1.6 | 3.1 | 2.6 | 0.5 | 3.8 | 1.9 | 2.1 | 0.8 | 3.1 | 2.9 |
| Asia | 4.5 | 4.4 | 5.3 | 3.8 | 5.3 | 4.0 | 5.4 | 3.0 | 5.1 | 3.6 |
| C&S America | 6.1 | 22.7 | 4.0 | 5.7 | 23.0 | 19.6 | 9.4 | 3.2 | 24.2 | 20.7 |
| EU | 1.4 | 12.8 | 1.6 | 1.4 | 11.6 | 14.4 | 2.0 | 0.7 | 12.4 | 12.8 |
| High income countries | 20.2 | 22.9 | 21.6 | 19.0 | 23.5 | 21.3 | 26.2 | 11.2 | 26.4 | 18.3 |
| Net-exports of biofuel crops, 2020 (US$ billion, real 2001) | | | | | | | | | | |
| Africa | −1.1 | 1.8 | 0.0 | −2.4 | 3.0 | 0.0 | −0.6 | −1.7 | 2.3 | 1.1 |
| Asia | −25.5 | −18.9 | −26.1 | −24.2 | −19.3 | −18.6 | −26.5 | −25.3 | −19.9 | −18.6 |
| C&S America | 27.7 | 32.2 | 31.2 | 23.4 | 35.1 | 28.2 | 29.1 | 26.2 | 32.7 | 31.5 |
| EU | −17.6 | −38.2 | −22.7 | −11.0 | −44.1 | −27.8 | −18.0 | −17.3 | −37.5 | −38.5 |
| High income countries | 9.7 | 15.4 | 7.9 | 10.9 | 14.3 | 15.3 | 8.8 | 11.4 | 14.0 | 17.6 |